§43. Validation of Bootstrap Current Models in LHD Plasmas

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Bootstrap current calculations with the neoclassical SPBSC [1] and VENUS+δf codes have been performed on experimental Large Helical Device (LHD, NIFS, Japan) configurations with different magnetic axis positions and simplified plasma density and temperature profiles [2]. In this paper, we use experimentally obtained plasma density and temperature profiles for the LHD discharges #61863 and #82582 [3] to compute the corresponding magnetohydrodynamic equilibrium states with an improved collisional operator [4] in the VENUS+δf code.

The bootstrap current flux derivatives dJ_{BS}/ds as a function of the normalized flux s for the LHD discharge #61863 are presented in Figure 1. The SPBSC and the TERPSICHORE code results in the collisionless limit are shown as triangles and by the red solid line, respectively. The integration of the dJ_{BS}/ds function gives a total bootstrap current J_{BS} of 18 kA from the TERPSICHORE code, J_{BS} of 10 kA from the SPBSC code in the collisionless regime and 27 kA from the SPBSC code using the connection formula for the given experimental conditions.

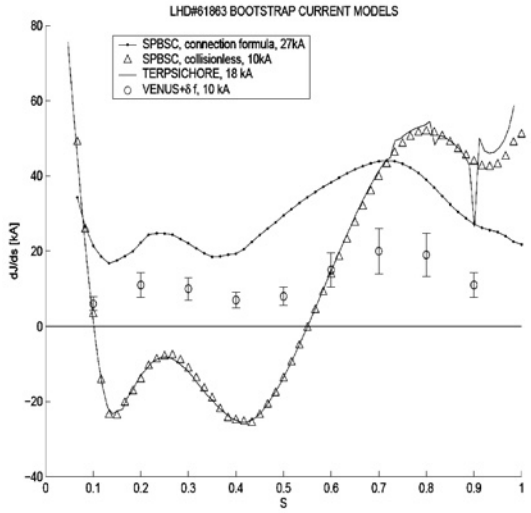

Fig.1. The LHD#61863 $R_{axis}=3.90m$ bootstrap current derivative dJ_{BC}/ds versus the flux label s calculated with the SPBSC code in the collisionless limit (triangles), with the connection formula (blue dotted line), with the TERPSICHORE code (red solid line) and with the VENUS+δf code(circles).

The total bootstrap current J_{BS} of 10 kA, calculated with the VENUS+δf code, is shown as circles with Monte Carlo error bars of 20%, which is in a good agreement with the experimentally obtained total bootstrap current of 10 kA.

Bootstrap current derivatives dJ_{BS}/ds as a function of the normalized flux s are presented in Figure 2 with triangles (calculated with the SPBSC code in the collisionless limit), with the red solid line (TERPSICHORE code, collisionless limit), with the blue dotted line (SPBSC code, the connection formula) and with circles plus error bars from the VENUS+δf code. The integration of the dJ_{BS}/ds function, obtained in the collisionless limit with the SPBSC and the TERPSICHORE codes, yields small negative total bootstrap currents J_{BS} of about -2 kA. The connection formula, implemented in the SPBSC code, gives a total bootstrap current J_{BS} of -5.5 kA. The total bootstrap current, calculated with the VENUS+δf code is equal to -8±2 kA, which corresponds to the experimentally measured total current of -14 kA within a factor of 1-2.

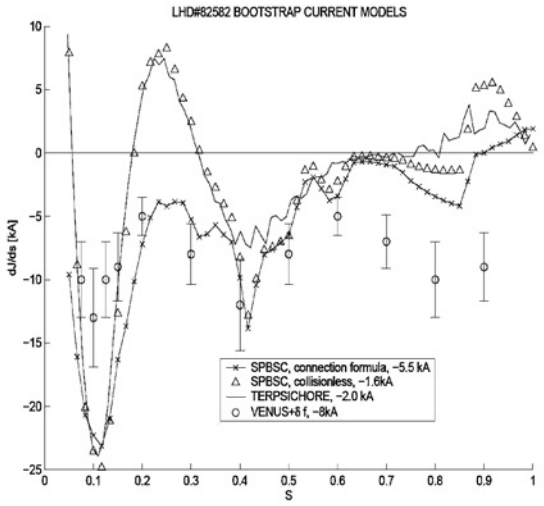

Fig.2. The LHD#82582 $R_{axis}=4.05m$ bootstrap current derivative dJ_{BC}/ds versus the flux label s calculated with the SPBSC code in the collisionless limit (triangles), with the connection formula (blue dotted line), with the TERPSICHORE code (red solid line) and with the VENUS+δf code(circles).

More accurate bootstrap current simulations will include in the future the electric field and inductive current effects as well as the non-equal impact of electrons and ions.

[1] K.Y.Watanabe et al, *Nucl. Fusion* **35**, 335(1995).
[2] M.Yu.Isaev et al, *Nucl. Fusion* **49**, 075013 (2009).
[3] Y.Nakamura et al, *22nd IAEA FEC*, Switzerland, EX/P6-20 (2008).
[4] S.Satake et al., *Plasma&Fus.Res.* **3**, S1062(2008).